Last Name:_______________First Name__________________Network-ID____________
Discussion Section:_________Discussion TA Name:_______________________________

Instructions—
Turn off your cell phone and put it away.
You may not share your calculator. Please keep it on your own desk.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil; do **not** use a mechanical pencil or a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.

2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.

3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter "I" and the numeral "1" and for the letter "O" and the numeral "0". **Do not** mark the hyphen circle at the bottom of any of these columns.

4. **This Exam Booklet is Version A**. Mark the **A** circle in the **TEST FORM** box at the bottom of the front side of your answer sheet.

5. Stop **now** and double-check that you have bubbled-in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.

6. Do **not** write in or mark any of the circles in the STUDENT NUMBER or SECTION boxes.

7. On the **SECTION** *line*, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)

8. Sign **(DO NOT PRINT)** your name on the **STUDENT SIGNATURE** *line*.

Before starting work, check to make sure that your test booklet is complete. You should have 11 ***numbered pages*** *plus two Formula Sheets.*

*Academic Integrity—***Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

Exam Grading Policy—
The exam is worth a total of 106 points, and is composed of three types of questions:

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.
(a) If you mark only one answer and it is the correct answer,
you earn **6** points.
(b) If you mark *two* answers, one of which is the correct answer,
you earn **3** points.
(c) If you mark *three* answers, one of which is the correct answer, you earn **2** points.
(d) If you mark no answers, or more than *three*, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points.*
No partial credit.
(a) If you mark only one answer and it is the correct answer,
you earn **3** points.
(b) If you mark a wrong answer or no answers, you earn **0** points.

TF: *true-false questions, each worth 2 points.*
No partial credit.

(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 m/s^2 *downward and ignore any effects due to air resistance.*

A more complicated formula is given by the formula sheet, but the essence is this: the pressure P(d) at depth d is given by P(d) = P(0) + rho g d.

1. A diver swims to a depth of 3.2 m in a freshwater lake. What is the increase in the force pushing on her eardrum, compared to what it was at the lake surface? The area of her eardrum is 0.60 cm^2. The density of water is $\rho_w = 1000$ kg/m^3.

(You must assume that she never swallows saliva while diving!)

a. 0.0 N
b. 1.9 N
c. 3.4 N
d. 7.3 N
e. 11.7 N

```
P(d) = P(0) + rho g d = P(0) + 1000 x 3.2 x 9.8
So the pressure increase is 3136 Pa.

F = P A = 31360 x 0.6 x 10^{-4} = 1.88 N,
if her internal pressure is still P(0), the atmospheric
pressure at the lake surface.
```

1 cm^2 = 10^{-4} m^2

The following 2 questions concern related physical situations:

A 0.20 kg mass is attached to a massless spring and allowed to oscillate around an equilibrium according to: y(t) = 2.7*sin(1.1*t), where y is measured in meters and t in seconds.

2. What is the position of the mass at t = 3.0 seconds?

a. −0.43 m
b. 0.19 m
c. −1.33 m

```
y(3) = 2.7 x sin(3.3)= - 0.4259 m

Note: 3.3 is in radians, so it is 180 x (3.3/\pi)
     = 189.1 deg.
```

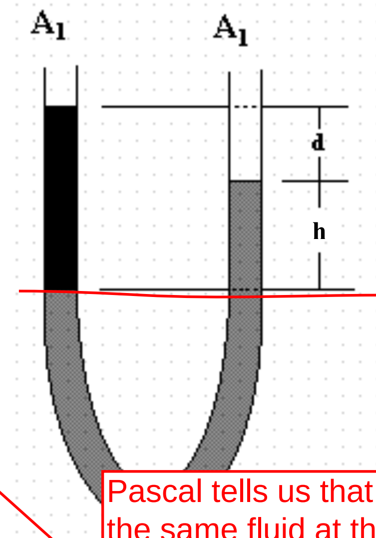
3. What is the maximum speed of the mass?

Recall the harmonic-circular motion correspondence

a. 2.7 m/s
b. 3.0 m/s
c. 3.4 m/s
d. 5.5 m/s
e. 9.3 m/s

```
Max speed is A x omega = 2.7 x 1.1 = 2.97 m/s
```

The following 2 questions concern related physical situations:



Two incompressible fluids are placed in a U-tube as shown in the figure to the right. Both ends of the tube are open. The tube has a cross sectional area $A_1 = 0.02\ m^2$. One fluid is water (light gray), with density of $\rho_w = 1000\ kg/m^3$. The second fluid is oil (black), with $\rho_o = 950\ kg/m^3$. The column of water is observed to be a distance h = 0.23 m above the point where the water meets the oil.

4. How high, d, does the oil rise above the water?

a. 5.00 m
b. 0.21 m
c. 0.005 m
d. 0.034 m
e. 0.012 m

Pressure at the \`red line' is:
Left: P = P(0) + 950 (d+h)g,
Right: P = P(0) + 1000 hg,
so
950(d+h) = 1000h or 950d = 50 h.
Thus, d = 50 x 0.23/950 = 0.0121 m.

Pascal tells us that in the same fluid at the same height, the pressure must be the same.

5. If instead the two ends of the tube were tightly sealed, what could be done to make it so the top of the two columns were at the same height so that d=0?

a. Pump air out of the left side of the tube so that it is at lower pressure.
b. Pump air out of the right side of the tube so that it is at lower pressure.
c. It is not possible to make d=0.

To make d = 0, P(0) on the left side must be larger than that on the right side.

This follows from Newton's second law:
Ma = T - Mg, so T = m(a+g) = mg'.

6. A pendulum consists of an object of mass m = 2.2 kg at the end of a string of length L = 2 m. The pendulum is in an elevator that is accelerating downward at 3 m/s^2. What is the period of the pendulum in the accelerating elevator?

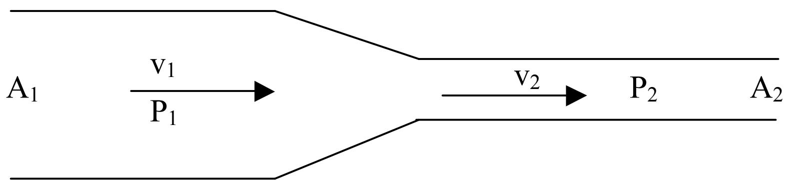
a. 0.6 s
b. 1.7 s
c. 2.2 s
d. 3.4 s
e. 4.4 s

The effective acceleration of gravity is
g' = 9.8 - 3 = 6.8.
Therefore,
T = 2\pi\sqrt{L/g'}
= 2\pi\sqrt{2/6.8} = 3.407 s.

In our case, the acceleration is downward, so a < 0.

The following 2 questions concern related physical situations:

An incompressible fluid is moving through a tube. It is originally in the wide part of the tube with cross sectional area $A_1 = 0.44\ m^2$ moving at speed $v_1 = 6.7$ m/s. The fluid then moves into a narrower section of tube with cross sectional area $A_2 = 0.17\ m^2$.



7. Given the pressure in the fluid, P_1, in the wide part of the tube, which of the following is a valid expression for the pressure P_2 in the narrow part of the tube?

a. $P_2 = P_1 + \frac{1}{2}\rho\left(v_1^2 - v_2^2\right)$

This is simply Bernoulli.

b. $P_2 = P_1 + \rho g v_2$

c. $P_2 = P_1 \frac{A_2}{A_1}$

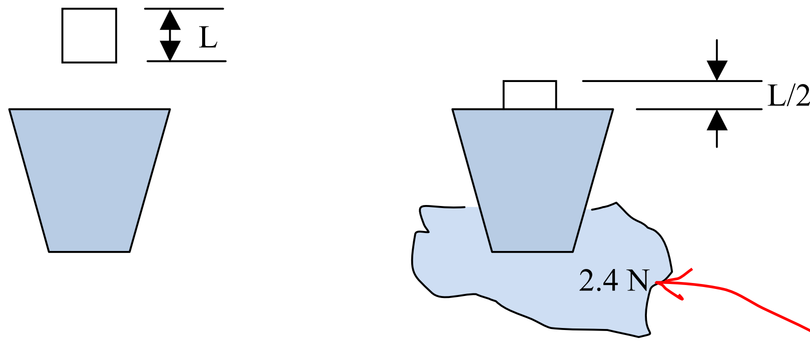
8. What is the speed of the fluid in the narrow section of tube, v_2?

a. 3.0 m/s
b. 6.7 m/s
c. 9.9 m/s
d. 12.7 m/s
e. 17.3 m/s

```
Thanks to continuity
     A_1 v_1 = A_2 v_2.
so
     v_2 = v_1 (A_1/A_2) = 6.7(0.44/0.17) = 17.34 m/s
```

The next 2 questions concern the following situation:

A cube of unknown material is $L = 0.1$ m on each side. The cube is placed in a container of fluid that is originally filled to the brim. It is observed that one-half of the cube is submerged in the fluid and an amount of fluid weighing 2.4 N has spilled from the container.



9. What is the density of the cube, ρ_c?

a. 245 kg/m^3
b. 332 kg/m^3
c. 750 kg/m^3
d. 500 kg/m^3
e. 1000 kg/m^3

```
The weight of the displaced liguid is 2.4 N.
Archimedes tells us this is the buoyant force, so
The mass M of the cube is M = 2.4/g.  The volume V
= 0.1^3.  Therefore,
rho_c = M/V = 2.4/(g x 0.1^3) = 244.9 kg/m^3.
```

10. How does the density of the fluid, ρ_f, compare to the density of the cube?

a. $\rho_f > \rho_c$
b. $\rho_f = \rho_c$
c. $\rho_f < \rho_c$

```
Of course!
```

The next two questions refer to the following situation:
A 3kg mass is attached to a massless spring with constant k = 24 N/m. It is stretched 0.15 m away from its equilibrium position. At time t = 0 the mass is released.

11. What is the total energy of the block?

a. 0.03 J
b. 0.17 J
c. 0.27 J

```
U = (1/2) k A^2 = (1/2)24 x 0.15^2 = 0.27 J.
```

Initially, all the mechanical energy is in the potential form. A = 0.15m

12. What is the period of oscillation?

a. 1.97 s
b. 2.22 s
c. 6.53 s

```
T = 2\pi \sqrt{m/k} = 2\pi \sqrt{3/24} = 2.221 s.
```

13. An aluminum plate has a circular hole cut in it. An aluminum ball (solid sphere) has exactly the same diameter as the hole when both are at room temperature, and hence can just barely be pushed through it. If both the plate and the ball are now heated up to a few hundred degrees Celsius, how will the ball and the hole fit?

a. The ball won't fit through the hole any more.
b. The ball will fit more easily through the hole.
c. Same as at room temperature.

on the formula sheet

14. What is the root mean square speed of an oxygen molecule in this room?

?

a. 5.1 m/s
b. 510 m/s
c. 510,000 m/s

```
The easiest way is to use v^2 = 3RT/M,
where R = 8.31, T = 300, and M = 0.032 (in kg!).
Therefore, v^2 = 233719, so v = 483 m/s. For
nitrogen, the answer seems closer (517 m/s).
```

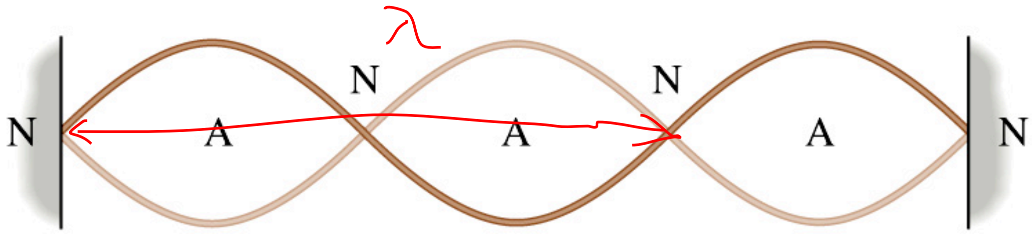
15. A balloon is filled at atmospheric pressure (1.01×10^5 Pa), and at 20 degrees Celsius with an ideal gas to a volume of 0.01 m^3. How many molecules of gas are in the balloon?

a. 0.28×10^{23}
b. 1.2×10^{23}
c. 2.5×10^{23}

```
PV = Nk_BT, so
N = PV/k_BT = 1.01 x 10^5 x 0.01/1.38 x10^{-23}x293
  = 1.01 x10^{26}/404.3 = 2.5 x 10^{23}.
```

The next two questions refer to the following situation:

A string is stretched between two supports that are 2.2 m apart. A standing wave is observed with two nodes as shown in the figure.



16. The frequency of the oscillation is observed to be f = 500 Hz. What is the speed of the wave?

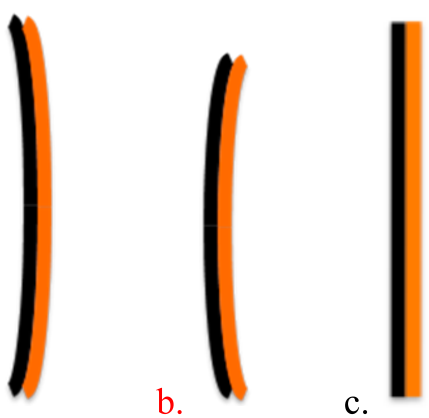
lambda = 2.2 x(2/3) = 1.46 m
Therefore, v = 500 \lambda = 733 m/s

a. 733 m/s
b. 502 m/s
c. 1110 m/s
d. 214 m/s
e. 662 m/s

17. This standing wave is oscillating in the fundamental mode.

a. True
b. False

18. A bimetallic strip (see diagram) is made with aluminum $\alpha=16\text{x}10^{-6}$ /K ***on the left***, and iron $\alpha = 12\text{x}10^{-6}$ /K ***on the right***. At room temperature, the lengths of metal are equal. If you heat the strips up, what will it look like?



a. b. c.

The left strip responds more to temperature changes.

19. After a grueling work out, you drink a liter (1 kg) of cold water (1° C). How many Calories does it take for your body to raise the water up to body temperature of 37° C?

a. 3.6 Cal
b. 36 Cal
c. 360 Cal

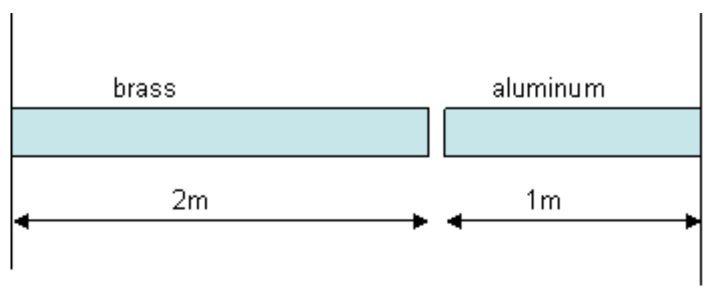
not in the scope of HE3 of Fall10

20. How much ice (at 0° C) do you need to add to 0.5 liters of water at 25° C to cool it down to 10° C? The latent heat *L* for ice melting is 80 cal/gram and the specific heat *c* for water is 1 cal/gram C).

a. 51 gram
b. 83 gram
c. 101 gram
d. 122 gram
e. 150 gram

not in the scope of HE3 of Fall10

21. In the picture (drawing not to scale), the brass and aluminum bars are attached to immovable walls. The linear thermal expansion coefficients for brass and aluminum are $\alpha_{Brass} = 19 \times 10^{-6}\ C^{-1}$ and $\alpha_{Aluminum} = 23 \times 10^{-6}\ C^{-1}$. At 26.7 degrees Celsius the air gap between the rods is 1.3×10^{-3} m. At what temperature, T (in degrees Celsius), will the gap be closed?



a. 18 C
b. 22 C
c. 32 C
d. 41 C
e. 48 C

This is exactly D13-3

The following two questions pertain to the same situation.

22. At an air show, an airplane is flying by you at 200 m/s. If you hear the frequency of the sound from the airplane is 310 Hz when it s flying away from you, what frequency will you hear as the airplane flies toward you? (Assume that the speed of sound is v = 340 m/s).

a. 129 Hz
b. 240 Hz
c. 570 Hz
d. 800 Hz
e. 1196 Hz

```
Let f_s be the source frequency.
     310 = f_s x 340/(340+200).
Let f be the frequency you want:
     f = f_s x 340/(340-200).
Therefore,
f/310 = 540/140, so
f = 1195.7 Hz.
```

v_s < 0, because the airplane is flying in the opposite direction of the sound wave being observed.

23. The sound of the engine of the airplane is 95 dB when it is 500 meters away from you. How loud is the engine to you when it is 5,000 meters away from you?

a. 75 dB
b. 85 dB
c. 95 dB
d. 105 dB
e. 115 dB

```
Let I_1 be the intensity of the sound at 500 m and
I_2 that at 5000 m. By definition
     10 log_{10}(I_1/I_0) = 95 dB
I = P/(4\pi r^2) implies I_1 x 500^2 = I_2 x 5000^2,
that is, I_2 = I_1/100.  Therefore, the loudness \b at
5000 m is
     \b = 10 log_{10}(I_2/I_0)
        = 10 log_{10}[(I_2/I_1)(I_1/I_0)]
        = 10 log_{10}(I_1/I_0) + 10 log_{10}(1/100)
        = 95 - 10 log_{10}(100) = 75 dB
```

This exam continues on the next page.

24. In Lab 7 (Investigation of Periodic Motion), you added the potential energy (P.E.) and kinetic energy (K.E.) of a mass undergoing periodic motion attached to a spring. You found that the sum was constant. The relative phase of the individual graphs of PE and KE vs. time is:

a. 0° (in phase)
b. 90°
c. 180° (out of phase)

When K is max, U is min, and vice versa, so they are out of phase.

25. In the Standing Waves experiment, you found the relationship between frequency (f) and length (l) of various pipes. True or False: We found the frequency is directly proportional to the length.

a. True
b. False

v = lambda f = constant, and lambda is proportional to L, so f is proportional to 1/L, roughly speaking.

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?